Automated Channel Routing to Reduce Energy Use in Wastewater UV Disinfection Systems

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DECEMBER 2005

Given their intensive energy demands, wastewater treatment plants provide many high-return opportunities for energy conservation projects. Even well-designed, relatively new wastewater treatment facilities can often be enhanced to significantly decrease energy use. Several innovative ideas to reduce energy consumption have recently been applied at the UC Davis Wastewater Treatment Plant (WWTP), which became operational in 2000.

The UC Davis WWTP has an annual average design capacity of 2.5 million gallons per day (Mgd) and provides wastewater treatment for the 3,600-acre main campus. Treatment processes include a three-channel oxidation ditch, clarifiers, sand filter cells, and ultraviolet light (UV) disinfection. Solids handling processes for waste activated sludge include solids storage basins (SSB) and solids drying beds. Thus, the UC Davis WWTP is similar to many small municipal wastewater treatment plants currently in use in California and across the United States.

Following commissioning, the University evaluated the WWTP and identified two major design changes predicted to reduce energy consumption. The first concept was to establish a dissolved oxygen (DO) feedback loop to control variable frequency drives (VFDs) on the motors used to aerate the oxidation ditches. The second concept was to establish an automated means to provide greater turndown for the UV disinfection system during low-flow conditions. These plant modifications were subsequently designed and implemented by UC Davis in partnership with the California Department of Water Resources (DWR), funded under DWR Contract 4600002347. This report describes and evaluates the UV disinfection project.

Our principal conclusions are as follows:

- UV disinfection can remain effective while using less energy than dictated by traditional designs, which often ignore off-peak operating modes.

- The energy savings as a result of these changes is significant. Once fully implemented, annual energy use by the UV system is expected to drop 25%. Additionally, UV bulb life will be extended by a like amount, with a resultant savings in bulb replacement costs. Based on energy savings alone, the project is estimated to have a 4-year payback at the prevailing municipal electrical rate of $0.09/kWh

- Maintaining proper disinfection when a channel is brought back into service requires careful design consideration. Bacterial growth can occur in treated water after being stored in an “off” channel for several hours. In-channel circulation of the stored water during start-up is recommended to maintain water quality.

Existing plants with multiple channels and limited turn-down should consider process control changes like those implemented at UC Davis as a way to reduce operating costs. New UV disinfection systems should reflect this concept during design by providing efficient energy use with proper disinfection over the full range of operating conditions.

1.1 Plant Description

The UC Davis wastewater treatment plant (WWTP), designed by Brown and Caldwell, was commissioned in March of 2000. Prior to that, wastewater from the campus was treated at a treatment plant that was constructed in 1949 and upgraded in 1970 and 1988. The University elected to construct a new WWTP when the old plant was facing tighter discharge requirements and reaching the end of its useful life.

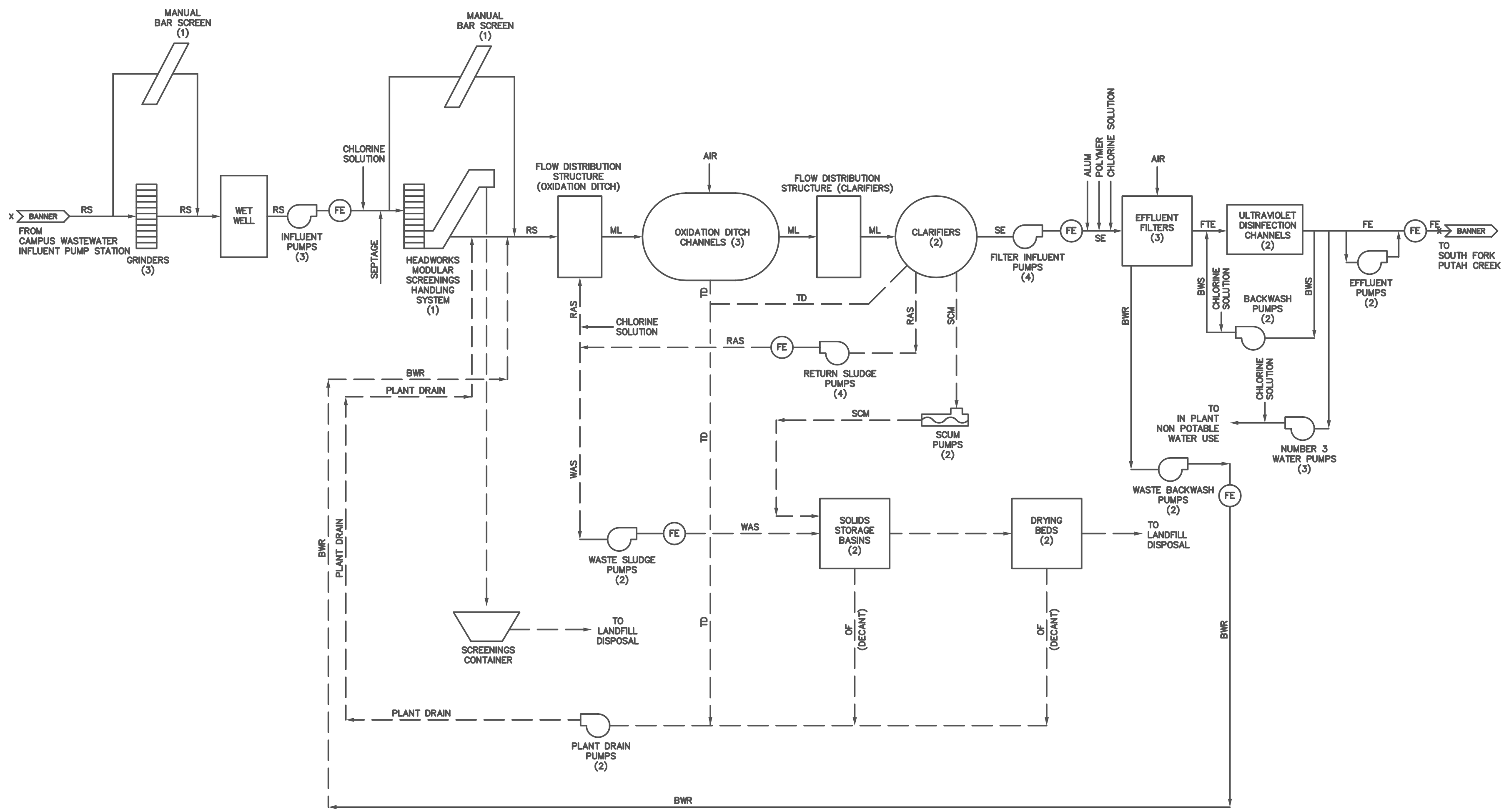
The new plant schematic is provided in Figure 1. Wastewater generated by the campus continues to flow to the old WWTP site and is then pumped to the new WWTP. The treatment plant was designed for an average-day flow of 2.5 million gallon per day (Mgd) and a peak hourly flow of 6.3 Mgd. Wastewater treatment processes include an oxidation ditch, clarifiers, sand filter cells, and ultraviolet light (UV) disinfection. Treated effluent is discharged to the South Fork of Putah Creek. Solids handling processes for waste activated sludge include solids storage basins (SSB) and solids drying beds. The dried solids are transported offsite for landfill disposal. Table 1-1 summarizes the treatment processes.

Table 1-1. Unit Processes at the UC Davis WWTP

Process	Description
Headworks	2 Channel Monsters® and 1 Auger Monster™
Oxidation Ditch	3 channels (Orbal by U.S. Filter/Envirex Inc.)
Clarifiers	2 clarifiers
Filters	3 filters (Hydro-Clear®)
UV Disinfection	2 channels (Trojan 3000)
Solids Storage Basins (SSBs)	2 basins
Solids Drying Beds	2 beds

1.2 Discharge Requirements

The UC Davis WWTP operates within an extremely strict discharge permit issued by the Central Valley Regional Water Quality Control Board under the National Pollutant Discharge Elimination System (NPDES). Tables 1-2 and 1-3 list key effluent limits. The permit requires the treated wastewater to meet California's "Title 22" water reclamation criteria. The plant has been producing high quality effluent since its commissioning.



UC Davis Wastewater Treatment Processes Schematic

Table 1-2. NPDES Permit Effluent Limits for Conventional Pollutants

Constituents	Units	Monthly Average	Weekly Average	7-Day Median	Daily Average	Daily Maximum
BOD	mg/L	10**	15**	---	---	25**
	lb/day***	225	338	---	---	560
Total Suspended Solids	mg/L	10**	15**	---	---	25**
	lb/day***	225	338	---	---	560
Total Coliform Organisms	MPN/ 100ml	---	---	2.2	---	23
Settleable Solids	Ml/l	---	---	---	---	0.1
Turbidity	NTU	---	---	---	2	5*

*) The turbidity shall not exceed 5 NTU more than 5 percent of the time within a 24-hour period. At no time shall the turbidity exceed 10 NTU.
**) To be ascertained by a 24- hour composite.
***) Based upon a permit dry-weather treatment capacity of 2.7 Mgd

Table 1-3. Additional NPDES Effluent Permit Limits

Constituents	Units	Monthly Average	4-Day Average	Daily Average	1-Hour Average
Total Residual Chlorine	mg/L	---	0.01	---	0.02
	lbs/day***	----	0.225	---	0.45
Ammonia (as N)	mg/L	pH based	---	---	pH based
	lbs/day***	---	---	---	---
Nitrate + Nitrite (as N)	mg/L	10	---	---	---
	lbs/day***	225	---	---	---
Aluminum	µg/*l*	---	87	---	750
	lbs/day***	---	1.9	---	16.8
Cyanide	µg/*l*	---	5.2	---	22
	lbs/day***	---	0.113	---	0.5
Copper	µg/*l*		Hardness based	---	---
	lbs/day***		---	---	---
Dichloromethane	µg/*l*	4.7	---	---	---
	lbs/day***	0.1	---	---	---
Dioxin/Furans	pg/ *l*	0.014	---	---	---
	lbs/day***	0	---	---	---
Iron	µg/*l*	300	---	---	---
	lbs/day***	6.8	---	---	---

***) Based upon a permit dry-weather treatment capacity of 2.7 Mgd

1.3 Electrical Use and Costs

During its first two years of operation, the UC Davis WWTP used an average of nearly 2,000,0000 kWh per year. UC Davis' average electricity cost is relatively low at \$0.054/kWh. Nonetheless, power costs for the WWTP account for nearly 10% of the \$1.1 million total annual cost to operate and maintain the plant.

1.4 Identification of Energy Reduction Opportunities

Following commissioning of the new plant, each of the major treatment processes was reviewed to identify potential energy reduction projects. Results from this survey are discussed below.

Headworks

Wastewater passes through a manual bar screen, and is then routed to two influent channels prior to entering the influent pump station. There are two "Channel Monster®" grinders installed in one of the channels. The two grinders were designed to run continuously, but we found that using the existing PLC to turn off one of the grinders during low flow periods reduced energy use without any adverse impacts. This design change was subsequently implemented during a previous project.

Oxidation Ditch

A 260 horsepower (hp) aeration system is installed in the three-ring oxidation ditch system. Under the original design, the amount of air supplied to the ditches is manually controlled based on the dissolved oxygen (DO) level. For optimal treatment, the manufacturer of the oxidation ditch (U.S. Filter/Envirex Inc.) recommends that the aerobic zone be maintained at a constant DO level of 2.0 mg/L. A DO level of less than 0.5 mg/L is recommended for the anoxic zone. Though the original design featured eight 2-speed motors capable of running both forward and reverse, for a total of five different aeration settings for each motor, it was difficult to operate the system close to the actual oxygen demand without over-aerating the wastewater. Over-aeration wastes energy and can cause undesirable changes in the biological characteristics of the wastewater. Replacing some of the existing two-speed motors with VFDs was identified as a means to reduce energy consumption. The installation of a reliable, continuously-monitoring DO device coupled with a feedback control loop to the VFDs would fully automate this improvement. These changes were subsequently designed and implemented by UC Davis in cooperation with the DWR, funded under DWR Contract 4600002347, and are discussed in a separate report.

Filter Influent Pump Station

The influent pump station consists of four 40-hp vertical turbine open line shaft pumps. All four pumps are operated under VFD. Partially treated water is pumped from the wetwell to the filter for further treatment. The survey identified that water levels could be maintained at a level 1.5' higher than the original setting. Implementing this change reduced the static head for the pump to pump water by 1.5' with the resultant reduction in energy consumption. This design change was immediately implemented.

UV Disinfection

The treatment plant uses UV light to disinfect the treated water. Ultraviolet disinfection has several advantages over traditional chlorine disinfection, most notably the elimination of safety concerns associated with accidental chemical releases and lack of chlorine disinfection by-products in the treated effluent. However, UV disinfection uses significantly more energy. Under the original design for UC Davis, the UV system accounts for 20% of the total electricity used by the plant. The design includes two channels, each with four banks of UV modules. A minimum of two UV banks must remain on when a channel is in use. The system was designed to keep both channels in operation except during maintenance. Thus, at least four UV banks are always on. When flows increase, the third banks in each channel are automatically turned on. The fourth banks in each channel are kept in reserve to provide back-up for any of the three operational banks. Given this design, UV power consumption is always fixed at either 67% or 100% of maximum consumption. A process control change to automatically divert all flow to one of the channels during low-flow periods would allow for a greater turn-down of UV power consumption. The revised system would be able to run at 33%, 50%, 67%, and 100% of maximum power. Information from the UV Design Guidelines (NWRI, December, 2000) affirm that the system could be modified as described and still maintain compliance with all permitted discharge limits. These changes were subsequently designed and implemented by UC Davis in cooperation with the DWR, funded under DWR Contract 4600002347, and are the focus of this report.

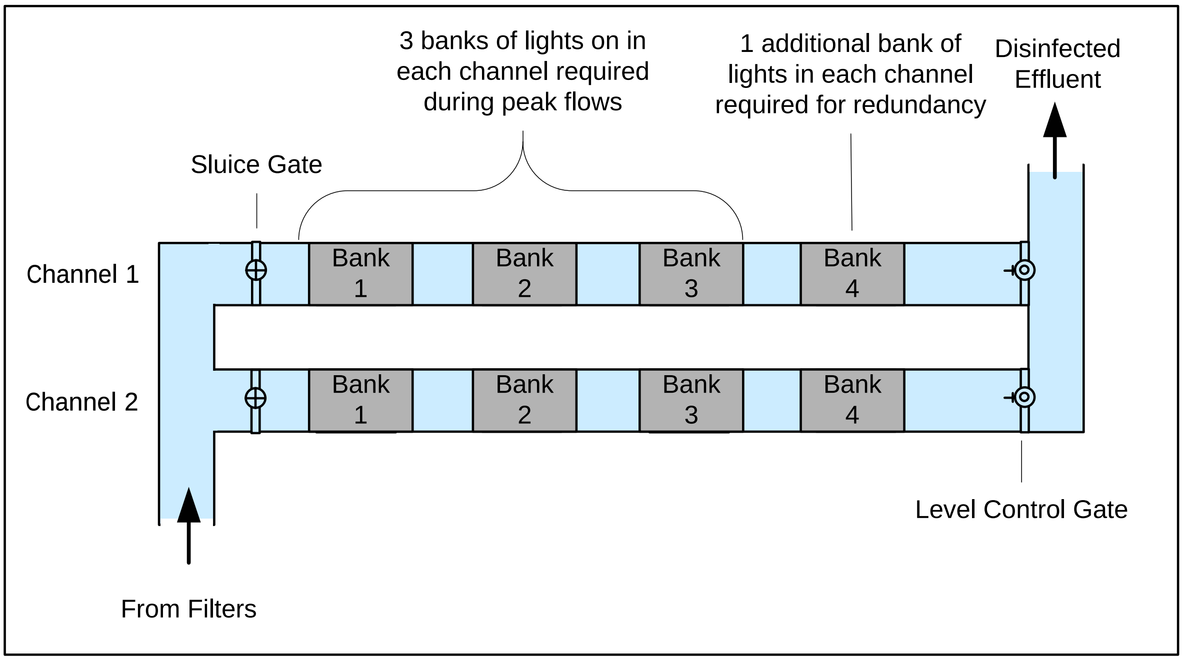
Solids Processing

The plant uses facultative ponds to digest its activated sludge. The water in each pond is circulated and aerated (within the surface layer) by two10-hp mixers. The survey found that one mixer could be turned off during the night and restarted the next morning without adversely affecting sludge treatment. This change was immediately implemented.

2.1 Original UV Disinfection Control

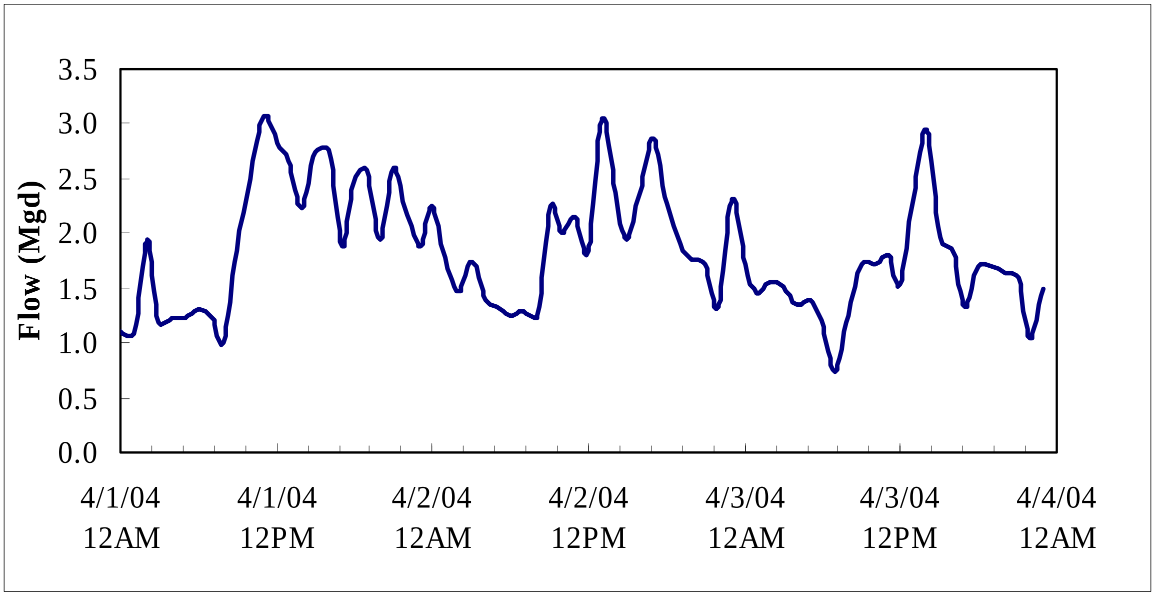
The original design had both UV channels in continuous use during normal operations (Figure 2-1). To maintain proper disinfection, a minimum of two UV banks must always be on in each operating channel regardless of flow and water quality. Thus, the original design only allowed two normal operating modes: either two banks of lights are on in each of the two channels or three banks of lights are on in each channel (the fourth banks provide redundancy for system failures). As a result, this typical small-plant design operates at 67% of peak-flow energy use during low-flow conditions.

Figure 2-1. UV Disinfection Configuration



Influent flows at UC Davis follow a fairly typical diurnal pattern (Figure 2-2). Under the original design conditions, the UV dose provided to each of the two channels was found to greatly exceed that needed for the disinfection. The UV dose was typically in the range of 400 to 500 mJ/cm2, which is significantly higher than the 100 mJ/cm2 specified by the UV Guidelines (2004). Experiments using plant effluent exposed to collimated beam of UV light have also confirmed that a 100 mJ/cm2 UV dose is sufficient for proper disinfection. These findings prompted us to explore opportunities for energy conservation via process control changes.

Figure 2-2. Typical hourly flow at UC Davis WWTP



3.1 Process Control Modifications

The central focus of our work was to develop a means to automatically route all wastewater flow through a single UV channel during periods of low demand. This simple concept would allow the UV system to operate with only two or three banks of lamps on, providing up to a 50% reduction in energy use during off-peak flow periods.

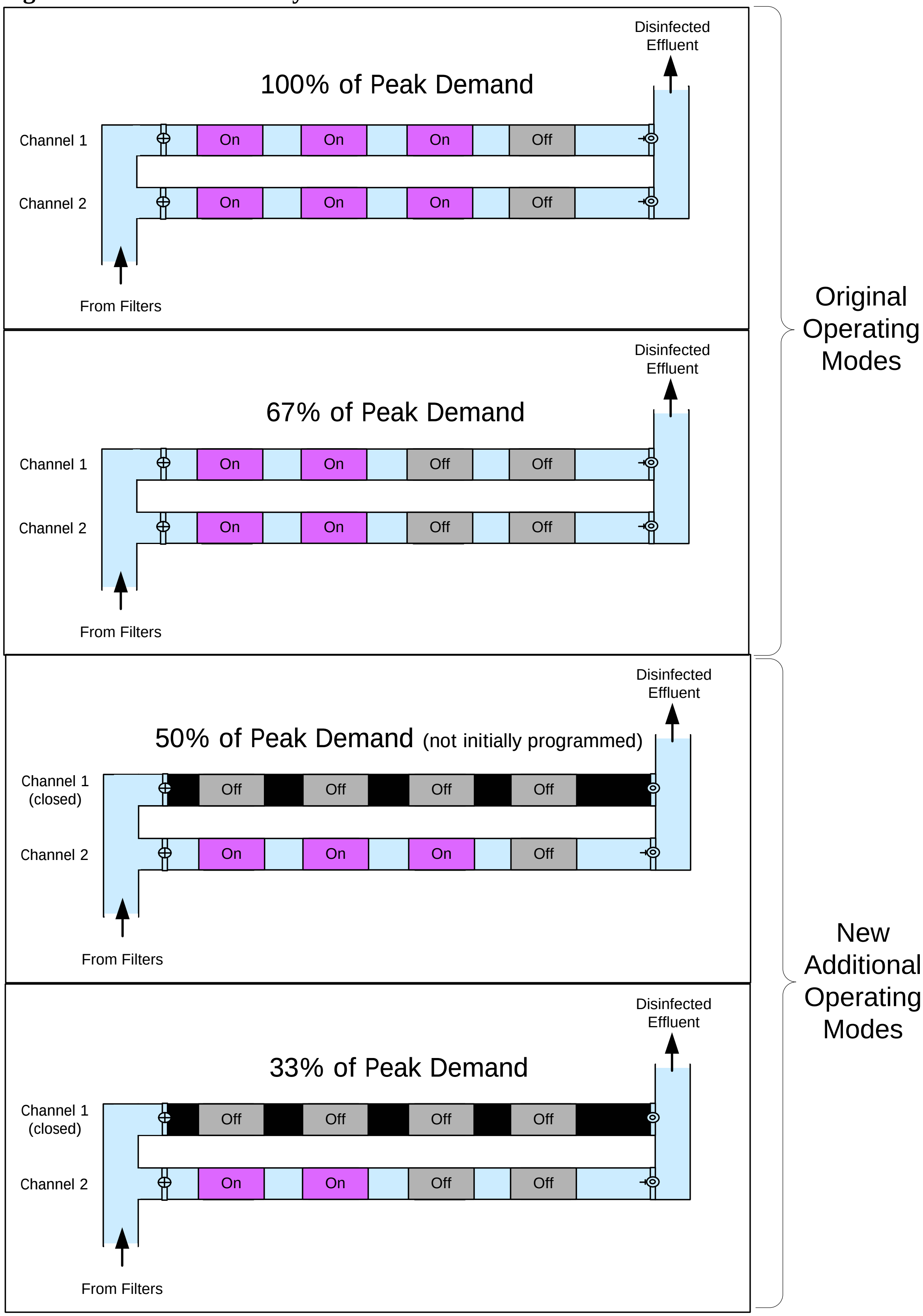
Implementation of this project required the installation of an automated control gate to divert flows and development of a new controls strategy based on measured flow and UV dose. The existing control system was replaced with an Allen-Bradley SLC-5/05 programmable controller (PLC). The new controls system continuously monitors flow and the delivered UV dose.

3.2 Control Strategy

When both the delivered UV dose and flow are below their set points, the PLC isolates one channel by operating an automated gate and then turns off all UV lamps in that channel. All disinfection is then accomplished via a single channel with at least two banks of UV lamps. The system status is continuously monitored and major alarms (e.g., channel gates failing to open/close) are immediately sent to on-call staff by the plant SCADA system.

Figure 3-1 illustrates all of the possible operating modes following project implementation.

Figure 3-1. Modified UV System Controls



4.1 Implementation

Modifications to the UV controls system were completed in December 2004. As-built drawings and PLC programming information are provided in Appendices A&B.

Tests were performed to evaluate single-channel operations under a variety of typical operating conditions to help select set points for control. Figure 4-1 shows typical weekday operation under currently programmed conditions. When the plant flow drops to below 2 Mgd near midnight, channel one closes and the lamps are turned off after an hour time of delay. The time delay is to keep the lamps from cycling on/off should the suddenly flow increase forcing the channel back into service. When the flow reaches 2 Mdg the next morning, channel one opens after the UV lamps have been turned on to ensure disinfection has occurred in the channel. Only one channel is typically required for the entire weekend, as the flow averages between 1.0 to 1.5 Mgd.

The PLC was programmed to isolate one of the channels when the operational UV dose is greater than 150 and the flow is less than 2.0 mgd. The UV dose set-point was set to ensure adequate disinfection. The flow set-point was set based on the hydraulic capacity of the flow channels. The channels are rated for flows in excess of 3.0 mgd, but 2.0 was selected as a conservative starting point.

4.2 Energy Use

Annual energy use by the UV system is expected to drop 25% following implementation of the project (see Figure 4-2). Additionally, overall UV bulb life will be extended by a like amount, with a resultant savings in bulb replacement costs. During the initial phases of testing, many of the set points were set much lower than necessary. We expect to raise the set points over time to increase the energy savings, as we gain experience and confidence in operating the system.

4.3 Design Challenges

The new controls scheme isolates flow into one of the channels, leaving treated water in the "off" channel. While this water is fully treated when the channel is isolated, we were concerned that water quality in the channel might degrade over time. In researching this concern, we found that bacterial growth did occur in the unused channel after long periods of non-use (e.g., 8 to 12 hours). This circumstance was anticipated, and the system was programmed with a "warm-up" period to turn the UV bulbs on for several minutes to disinfect the stored water before opening the isolation gate and putting the channel back in service. In practice, however, this protocol was not found to be completely effective due to the lack of circulation in the channel during the warm-up period. A "slug" of partially disinfected wastewater can remain at the end of the UV channel after the warm-up period. Proper UV disinfection requires flow past the UV bulbs. Thus, turning on the UV bulbs without circulating the water was not a reliable means of disinfecting the stored water.

Figure 4-1. Typical UV Dose Pacing with Flow

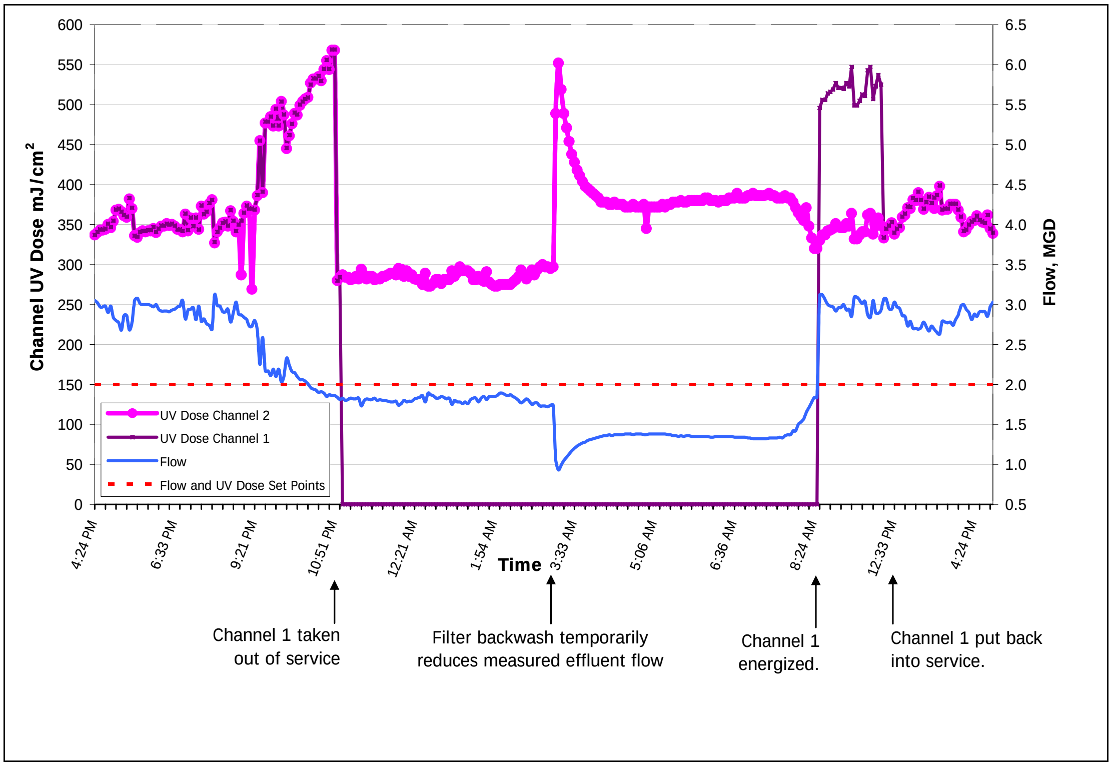
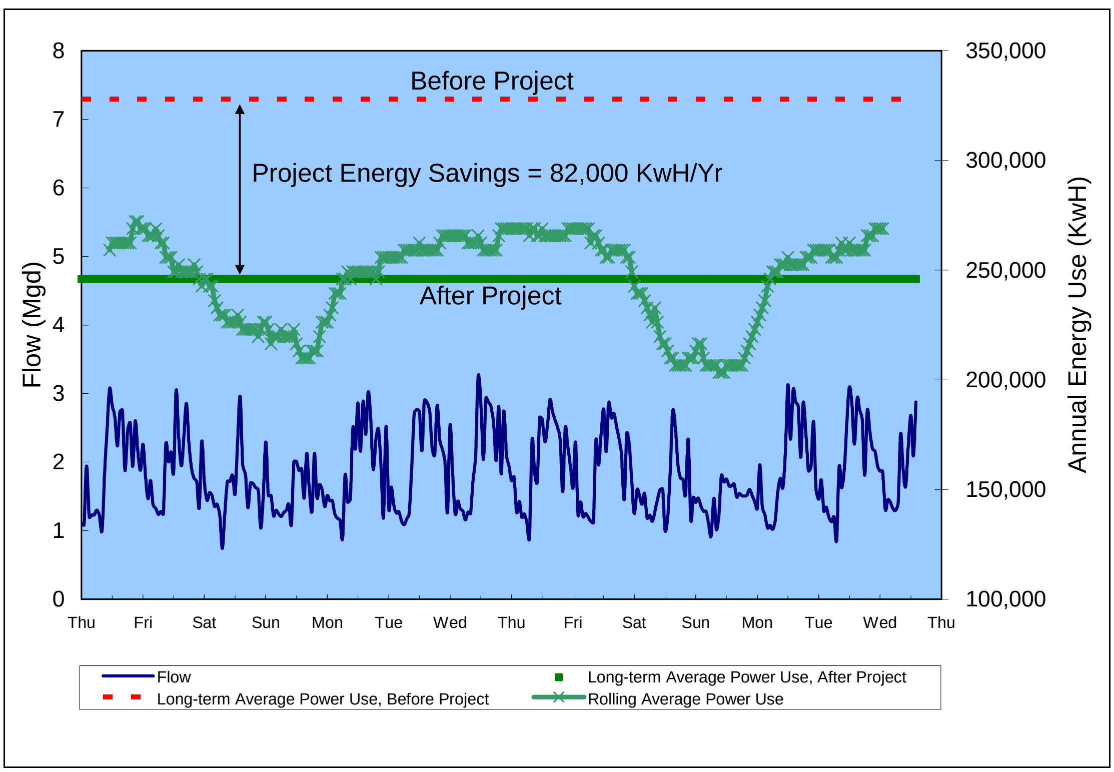


Figure 4-2. Energy Use Before and After Project



Additional design changes are required to refine the warm-up protocol in response to these findings. UC Davis is exploring the use of a small pump to circulate water in the channel during the warm-up period. This design change should allow UC Davis to implement full-time use of the new energy-conserving disinfection protocols.

Additional work is also required to improve the seal provided by the existing gate valve. Since the channel was not originally designed for complete isolation, some water has been found to leak through the valve seals.

The proposed process control enhancements for the UC Davis WWTP were relatively easy to implement and our data indicates that the project can significantly reduce energy use while maintaining water quality. Our principal conclusions are as follows:

- UV disinfection can remain effective while using much less energy than dictated by traditional designs, which often ignore off-peak operations.

- The energy savings as a result of these changes is significant. Once fully implemented, annual energy use by the UV system is expected to drop 25%. Additionally, UV bulb life will be extended by a like amount, with a resultant savings in bulb replacement costs. Based on energy savings alone, the project is estimated to have a 4-year payback at the prevailing municipal electrical rate of $0.09/kWh

- Maintaining proper disinfection during the start-up process requires careful design consideration. Re-growth of bacteria can occur in treated water if it is stored in the "off" channel for several hours. In-channel circulation during start-up is recommended to solve this.

- Design of the channel inlets and isolation valves are important considerations. Both should be designed for continuous use with zero leakage under the full range of design conditions.

These findings have broad application. Existing plants with multiple channels and limited turn-down should consider process control changes like those implemented at UC Davis as a way to reduce operating costs. New UV disinfection systems should reflect this concept during design by providing efficient energy use with proper disinfection over the full range of operating conditions.

Ultraviolet Disinfection Guidelines for Drinking Water and Water Reuse ies, *NWRI* (2004).

Kang, S.J.; Allbaugh, T.A.; Erickson, T.L.; Olmstead, K.P.; Thomas, L. and Thomas, P. (2004) Design and Operation of an ultraviolet disinfection system for a municipal wastewater treatment plant in Ypsilanti, Michigan. *WEFTEC Proceedings (2004)*

UV 3000 Operation and Maintenance Manual UC Davis *Trojan Technologies Inc.*

APPENDIX A

PCL PROGRAMMING DOCUMENTATION

Layout Drawing # CCZ1026AS01
SCC Drawing # 3E1026
PDC Drawing # 921249

1.0 Programmable Controller User Interface Device

1.1 The PLC shall be provided with a permanently mounted user interface device for displaying alarm messages and for entering variable values required by the PLC. The basis for system control is an Allen-Bradley SLC-5/05 programmable controller, which continuously monitors and controls the UV system's functions. The device shall be programmed to allow menu-based adjustment of all timers, flow setpoints, and other variables used by the PLC. Adjustable timers include lead bank rotation and bank time off delay.
The operator interface is an Allen-Bradley Panelview 600 Keypad Touch Screen Terminal with colour display.

CAUTION: Any changes made to the PLC program can and will affect the process being controlled. Do not attempt to make any changes to this program unless you are intimately familiar with the process.

2.0 Operational Description

Trojan Technologies, Inc shall provide an automatic dose paced control system. The control system shall be programmable logic controller (PLC) based and be fully capable of allowing lamps to be operated to maintain sufficient UV dose proportional to flow and UV demand while conserving power. Commands to turn UV banks on and off shall be retentive, such that operating banks will remain on, and non-energized banks will remain off, in the event of a PLC failure, and following restoration of power after a power failure. Other features shall be provided as specified herein.

A total of two (2) flow channel are provided for dose pacing. The flow channel contains three (3) U.V banks for disinfection purposes, and one (1) bank for redundant purposes. Each bank consists of 18 / 8 lamp modules. The system is designed with future expansion capabilities to three (3) channels with four (4) banks in each. Each bank is fed from a communications board, which controls and monitors the UV bank. This communications board is located within a Power Distribution Center (PDC) into which a power supply mains is fed. All communications to and from the PDC's originate from the PLC via an RS422 serial link. A 4-20 mA flow signal shall be transmitted to the PLC from the plant effluent flow meter. The system is rated at 3.80 MGD (peak flow) at the design effluent UV transmittance of 55%. The dose requirement will be 100 000 uWs/cm^2 with a retention time of 41.34 seconds.

The automatic dose pacing system shall operate as described in this document.

3.0 **General Requirements**

3.1 In Auto mode and under normal operating conditions, at least two (2) banks and one channel shall always stay on-line, regardless of the total effluent flow signal.

3.2 In the event of a disruption of power to the PLC, the battery backup shall retain the control program in memory.

3.3 The selection of banks to be energized shall be based on elapsed time.

3.4 Timers shall be accurate to 0.1 minutes or 0.1 hours.

3.5 All setpoints and deadbands will be field adjustable unless otherwise specified herein.

3.6 To avoid nuisance tripping all user alarms shall have an adjustable time delay from 1 to 60 minutes.

4.0 **Channel Operation**

4.1 To facilitate even wear on the lamps a "lead channel rotation" timer shall be provided for the lead channel such that the lead channel will rotate service. The initial setting shall be 168 hours, and the timer shall reset every time the lead channel rotates. Lead channel rotation shall be fully adjustable (1 - 999 hours). The lead channel rotation timer can also be disabled to prevent automatic lead channel cycling. When the automatic rotation is disabled, lead channel cycling will only be possible by toggling a manual rotation button located on the System Settings screen.

4.2 When a channel is requested to be in operation, either due to flowpacing requirements or a lead channel rotation, the requested channel will energize allowing it's banks to warm up for an adjustable period (1 to 10 minutes). When the banks have energized, an adjustable channel warm up (1 to 120 seconds) timer will begin timing, and when it expires the channel's slide gate will open.

This feature seems not available for flowpacing mode. Whenever the flow exceeds a setpoint, the channel gate opens right away without any delaying as shown above.

4.3 When a channel is requested to be taken out of operation due to flowpacing or lead channel rotation, a channel closing delay timer will begin timing (normally 10 minutes), and a bank time off timer will also begin timing (normally 30 minutes). When the channel closing delay timer has expired, the slide gate for the channel shall close. When the bank time off timer has expired, the lamps in that channel shall turn off. If the slide gate does not close within an adjustable time delay (normally 1 to 3 minutes) a slide gate failure alarm shall be initiated, and the lamps shall remain powered until an operator has cleared the alarm condition. The bank time off timer must be set so that it is longer than the channel closing delay plus the slide gate closing delay timers.

4.4 To avoid cycling of banks, an adjustable "bank time off delay" timer (initially set to 30 min, adjustable from .25 to 2 hr) shall be provided, so that when flow decreases below any setpoint, no bank will turn off until the time delay elapses. If flow increases above the setpoint during this delay period, the timer shall stop and reset itself to zero.

4.5 Every time the lead channel rotates, it shall rotate to the channel with the least elapsed time.
We need to disable the channel rotating for now until the other channel is modified without disrupting the bank lead/lag rotation.

4.6 Each channel shall have an "On/Off" status indicated. A channel is considered "On" if its banks are in Auto, and it's isolation gate is open, and all banks have warmed up.

4.7 Channels will have an operator selectable 'Out of Service' feature, which will allow them to be disabled from the Panelview screen, and therefore removed from the automatic control scheme. A channel will also be designated as 'Out of Service' if its slide gate is in local and closed or has a fail to start opening alarm, or if any bank in the channel has a major fault condition or is not in Remote Auto. When a channel is selected as 'Out of Service', it's associated slide gate will be requested to close. The banks in that channel will begin timing off and another channel will be called into service.
Remove this feature. When 'Out of Service' occurs, the banks shall remain on to ensure proper disinfection. Channel gate shall remain OPEN rather than CLOSE. Any major alarms shall notify operator to take corrective actions.

Note: You must put a channel's slide gate in manual to open it if all the banks in that channel are not in Auto mode.

5.0 <u>Bank Control - Dose Pacing</u>

5.1 Dose pacing will be applied to banks in "auto" mode only.

5.2 In Auto mode and under normal operating conditions, at least two (2) banks and one (1) channel shall always stay on-line, regardless of the total effluent flow signal.

5.3 An adjustable bank warm up timer shall be provided to mask any alarms that may be generated while the bank is warming up.

5.4 To prevent frequent bank cycling a "bank time off" timer dictates the amount of time required before an increase in dose affects the number of banks online.

5.5 As UV demand increases, by either an increase in flow or a decrease in UV Transmission or an increase in lamp hours, additional banks will be placed online accordingly.

5.6 When 3 banks in the lead channel are online, a UV demand increase will result in the lag channel opening and 2 banks operating in the lead and lag channels. Additional UV demand will result in 3 banks running in both the lead and lag channels.

5.7 The PLC will use the flow signal, UV Transmission value, and lamp hours to calculate the theoretical dose for all possible set points. These calculations then form the basis for automatic dose pacing.

5.8 A lamp hour reset feature shall be provided for each bank.

5.9 While in Auto mode, if any major fault condition affecting the UV output of the system exists the redundant bank will energize.
Whenever the bank is in Hand mode, the dose mode operation will be interrupted. We would like to see by turning Bank on Hand it should not interrupt the dose mode operation.

6.0 Water Level

When in Auto mode, the SCC will respond to a low water level input from a set of electrodes within each channel. After an operator adjustable time delay, a low water level alarm will be initiated. The banks will re-energize once the water level has returned above the level sensor setpoint. Under maintenance conditions, where an entire channel will be shut off and taken out of service, all of the remaining operating banks within the functioning channel should be turned on manually.

7.0 UV Transmission

One (1) UV transmission monitor will be provided for continuous monitoring of the system's effluent. Signal amplified to 4 - 20 mA. Range is 30 - 100%.

8.0 Minor Alarms

8.1 A "minor alarm" shall be displayed at the PLC panel and to indicate that maintenance attention is required. Alarms shall include:

- Individual Lamp Failure - indicates a single lamp failure that occurs which is not adjacent to another failed lamp and does not exceed the multiple lamp failure alarm set point.
- Low UV Intensity Warning - pre-set at the factory for 45% of the intensity after 100 hours. Alarm set point shall be field adjustable.
- Low UV Transmission - pre-set at the factory for 60% UV Transmission. Alarm set point shall be field adjustable.
- Low UV Dose - pre-set at the factory for 98 000 $\mu Ws/cm^2$. Alarm set point shall be field adjustable.
- UVT Out of Range – Indicates the UVT signal is outside the normal measurement limits.
- Low Water Level - indicates the condition where the water level within a channel drops to the top of the top lamp.

9.0 Major Alarms

9.1 A "major alarm" shall be displayed at the PLC panel for failure of any of the following components within the system:

- Low UV Intensity - pre-set at the factory for 25% of the intensity after 100 hours burn-in of the lamps. Alarm set point to be field adjustable.
- Low Low UV Transmission - pre-set at the factory for 55% UV Transmission. Alarm set point shall be field adjustable.
- Low Low UV Dose - pre-set at the factory for 94 000 μWs/cm^2. Alarm set point shall be field adjustable.
- Adjacent Lamp Failure – indicates that two or more lamps that are adjacent to one another have failed.
- Multiple Lamp Failure - indicates failure of more than 5% of lamps in a bank. This number shall be field adjustable.
- Module Failure - indicates when a current leakage to ground occurs or current draw over 8 amps of any single module occurs. Module failure shall also be indicated if a module is physically unplugged without its' relay being placed in the "OFF" position from the system control centre.
- Communications Fault - indicates communications failure between the PLC and the PDC.
- Bank Failure to Energize - indicates the failure to energize 30% or more of the modules within a bank.
- UVT Signal Failure – Indicates the UVT signal has been lost due to transmitter or cable fault.
- Flow Signal Failure – Indicates the flowmeter signal has been lost due to transmitter or cable fault.
- Not Enough Banks Available for Disinfection - indicates the failure of the UV PLC auto control of fulfilling the disinfection requirements at any given flow rate by not having enough banks available for disinfection.

A minimum of 20 most recent major alarms shall be recorded in an alarm history register on a first in - first out basis and shall be displayed when prompted.

10.0 UV PLC Communications

The UV PLC is the heart of the UV3000™ control system and must communicate with the Operator Interface and the Power Distribution Centres (PDC's)

The UV PLC and Operator Interface will be connected together via the Allen-Bradley Ethernet.

The UV PLC will communicate to the PDC's via an integral RS422 port. The PLC will poll each of the PDC's in sequence to continually update the status of the modules and lamps. All status information from one PDC (Bank) will be contained in one message string. The message string will be decoded by the PLC and checked for errors prior to making the status information available to the Operator Interface. Commands to control all aspects of the UV bank will be issued by the UV PLC through the RS422 serial link.

11.0 ISOLATION SLIDE GATE CONTROL

All slide gates shall have the following interconnects :

- A PLC/local status input, which will indicate if the gate is currently in field control (local), or PLC control (PLC). When this contact is closed, it will indicate that the gate is in field control.
- A close limit switch, which will indicate if the gate is fully closed. When this contact is closed, it will indicate the gate is in the closed position.
- An open limit switch, which will indicate if the gate is fully opened. When this contact is closed, it will indicate the gate is in the opened position.
- A close command input, which will allow the PLC to close the gate.
- An open command input, which will allow the PLC to open the gate.

All slide gates and Isolation Gates will have a PLC hand mode, which will allow the operator to open and close the gate from the operator interface. A channel with a slide gate that is in PLC hand mode will be available for dose pacing purposes if the slide gate is in the fully open position.

All Isolation Gates will operate in an Auto mode as described in section 4.

All slide gates and Isolation Gates will have the following alarms :

- Gate fail to open if open limit not reached within stroke time
- Gate fail to close if close limit not reached within stroke time
- Gate fail to start opening if close limit still set after stroke time
- Gate not in PLC auto
- Gate fail to start closing if open limit still set after stroke time

All slide gates and Isolation Gates will have an alarm reset button that will be used to clear the alarm conditions for that gate.

A cycle counter will be available for each channel that will track the number of times a channel is brought into operation. This counter will be able to be reset by the operator on the gate control screen.

12.0 PLC I/O LISTING

12.1 Analog Inputs – Card Slot 1

INPUT NO.	DESCRIPTION	RANGE	CONTROL TYPE
1	Plant Flow Signal	0 – 3.8 MGD	Analog 4-20mA
2	UV Transmission Signal	30 - 100%	Analog 4-20mA

12.2 Digital Inputs – Card Slot 3 – IA8

INPUT NO.	DESCRIPTION	CONTROL TYPE
1	Low Water Level Alarm Channel 1	Discrete Dry Contact
2	Low Water Level Alarm Channel 2	Discrete Dry Contact
3	Low Water Level Alarm Channel 3 (future)	Discrete Dry Contact
4	Spare	Discrete Dry Contact
5	Spare	Discrete Dry Contact
6	Spare	Discrete Dry Contact
7	Spare	Discrete Dry Contact
8	Spare	Discrete Dry Contact

Digital Inputs – Card Slot 5 – IA16 (new)

INPUT NO.	DESCRIPTION	CONTROL TYPE
1	Inlet Slide Gate 1 Remote/Local	Discrete Dry Contact
2	Inlet Slide Gate 1 Open Limit	Discrete Dry Contact
3	Inlet Slide Gate 1 Close Limit	Discrete Dry Contact
4	Outlet Slide Gate 1 Remote/Local	Discrete Dry Contact
5	Outlet Slide Gate 1 Open Limit	Discrete Dry Contact
6	Outlet Slide Gate 1 Close Limit	Discrete Dry Contact
7	Inlet Slide Gate 2 Remote/Local	Discrete Dry Contact
8	Inlet Slide Gate 2 Open Limit	Discrete Dry Contact
9	Inlet Slide Gate 2 Close Limit	Discrete Dry Contact
10	Outlet Slide Gate 2 Remote/Local	Discrete Dry Contact
11	Outlet Slide Gate 2 Open Limit	Discrete Dry Contact
12	Outlet Slide Gate 2 Close Limit	Discrete Dry Contact
13	Spare	Discrete Dry Contact
14	Spare	Discrete Dry Contact
15	Spare	Discrete Dry Contact
16	Spare	Discrete Dry Contact

12.3 Digital Outputs – Card Slot 4 – OA16

OUTPUT NO.	DESCRIPTION	CONTROL TYPE
1	Common Major Alarm	Discrete Dry Contact
2	Common Minor Alarm	Discrete Dry Contact
3	Bank 5011 On/Off Status	Discrete Dry Contact
4	Bank 5012 On/Off Status	Discrete Dry Contact
5	Bank 5013 On/Off Status	Discrete Dry Contact
6	Bank 5014 On/Off Status	Discrete Dry Contact
7	Bank 5021 On/Off Status	Discrete Dry Contact
8	Bank 5022 On/Off Status	Discrete Dry Contact
9	Bank 5023 On/Off Status	Discrete Dry Contact
10	Bank 5024 On/Off Status	Discrete Dry Contact
11	Bank 5031 On/Off Status (future)	Discrete Dry Contact
12	Bank 5032 On/Off Status (future)	Discrete Dry Contact
13	Bank 5033 On/Off Status (future)	Discrete Dry Contact
14	Spare	Discrete Dry Contact
15	Spare	Discrete Dry Contact
16	Spare	Discrete Dry Contact

Digital Outputs – Card Slot 6 – OA8 (new)

OUTPUT NO.	DESCRIPTION	CONTROL TYPE
1	Inlet Slide Gate 1 Open Command	Discrete Dry Contact
2	Inlet Slide Gate 1 Close Command	Discrete Dry Contact
3	Outlet Slide Gate 1 Open Command	Discrete Dry Contact
4	Outlet Slide Gate 1 Close Command	Discrete Dry Contact
5	Inlet Slide Gate 2 Open Command	Discrete Dry Contact
6	Inlet Slide Gate 2 Close Command	Discrete Dry Contact
7	Outlet Slide Gate 2 Open Command	Discrete Dry Contact
8	Outlet Slide Gate 2 Close Command	Discrete Dry Contact

TROJAN TECHNOLOGIES : SERIAL NUMBERS

PROJECT NAME:	UC DAVIS, CA.
MODEL:	TYPE "D" SCC
SERIAL NUMBER:	
kW RATING:	1.8 kW
SYSTEM VOLTAGE:	120V 1PH 50/60Hz
AMPS:	15 AMPS

PROJECT NAME:	UC DAVIS, CA.
MODEL:	BANK 5011 18UVM/8-64"
SERIAL NUMBER:	
kW RATING:	12.6 kW
SYSTEM VOLTAGE:	120/208V 3PH 50/60Hz
AMPS:	38.1 A

PROJECT NAME:	UC DAVIS
MODEL:	BANK 5012 18UVM/8-64"
SERIAL NUMBER:	
kW RATING:	12.6 kW
SYSTEM VOLTAGE:	120/208V 3PH 50/60Hz
AMPS:	38.1 A

PROJECT NAME:	UC DAVIS
MODEL:	BANK 5013 18UVM/8-64"
SERIAL NUMBER:	
kW RATING:	12.6 kW
SYSTEM VOLTAGE:	120/208V 3PH 50/60Hz
AMPS:	38.1 A

PROJECT NAME:	UC DAVIS
MODEL:	BANK 5014 18UVM/8-64"
SERIAL NUMBER:	
kW RATING:	12.6 kW
SYSTEM VOLTAGE:	120/208V 3PH 50/60Hz
AMPS:	38.1 A

PROJECT NAME:	UC DAVIS, CA.
MODEL:	BANK 5021 18UVM/8-64"
SERIAL NUMBER:	
kW RATING:	12.6 kW
SYSTEM VOLTAGE:	120/208V 3PH 50/60Hz
AMPS:	38.1 A

PROJECT NAME:	UC DAVIS
MODEL:	BANK 5022 18UVM/8-64"
SERIAL NUMBER:	
kW RATING:	12.6 kW
SYSTEM VOLTAGE:	120/208V 3PH 50/60Hz
AMPS:	38.1 A

PROJECT NAME:	UC DAVIS
MODEL:	BANK 5023 18UVM/8-64"
SERIAL NUMBER:	
kW RATING:	12.6 kW
SYSTEM VOLTAGE:	120/208V 3PH 50/60Hz
AMPS:	38.1 A

PROJECT NAME:	UC DAVIS
MODEL:	BANK 5024 18UVM/8-64"
SERIAL NUMBER:	
kW RATING:	12.6 kW
SYSTEM VOLTAGE:	120/208V 3PH 50/60Hz
AMPS:	38.1 A

SCC WIRING DIAGRAM#:	**3E1026**
PDC WIRING DIAGRAM#:	**921249**
LAYOUT DRAWING#:	**CCZ1026S01**

Revision History

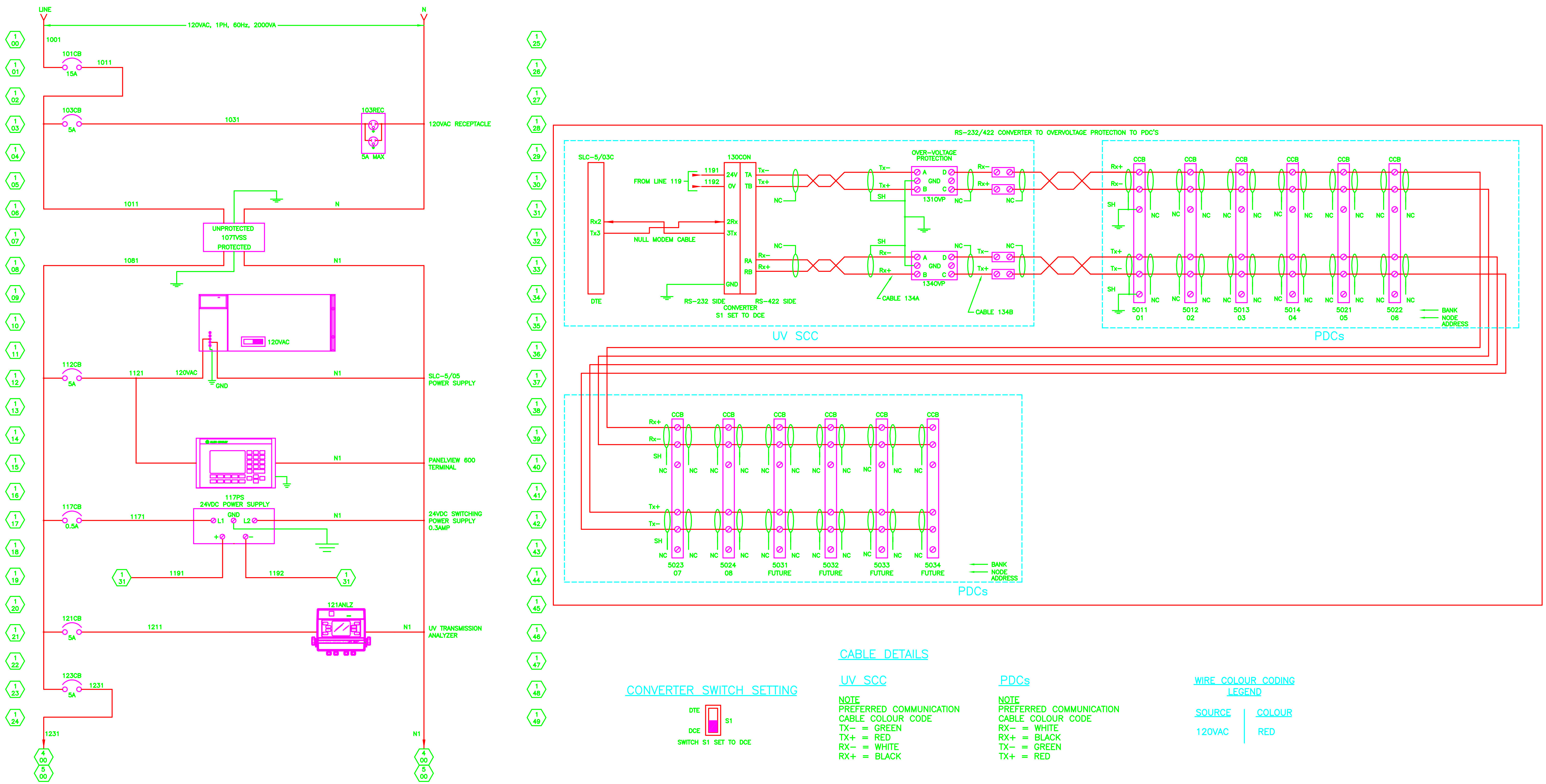
2.0 Change from A type controller to PLC.

- 2.1 Add alarms for instrument faults.
- 3.1 Changed PLC to 5/05 and updated HMI link to read Ethernet. May 11, 2004 - ML

APPENDIX B

AS-BUILT DRAWING

REV	REVISION DESCRIPTION	LOG NO.	REV BY	CHK BY	APPROVAL AND DATE
C	CHANGED FROM SLC5/03 TO SLC 5/05.	04-133	ABK	RSH	RSH 04MR17
D	ADDED I/O AS SPECIFIED BY SITE	04-820	RSH	SF	RSH 04JN03



CONVERTER SWITCH SETTING

DTE
DCE
S1
SWITCH S1 SET TO DCE

CABLE DETAILS

UV SCC

NOTE
PREFERRED COMMUNICATION CABLE COLOUR CODE
TX− = GREEN
TX+ = RED
RX− = WHITE
RX+ = BLACK

PDCs

NOTE
PREFERRED COMMUNICATION CABLE COLOUR CODE
RX− = WHITE
RX+ = BLACK
TX− = GREEN
TX+ = RED

WIRE COLOUR CODING LEGEND

SOURCE	COLOUR
120VAC	RED

CONTROLS SCHEMATIC

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES: 2 PL DEC ± N/A
3 PL DEC ± N/A
ANGLE ± N/A
REMOVE ALL BURRS
ALL CORNERS R 0.010 OR BREAK
∇ – MIN RECEIVING INSPECTION PT

TROJAN TECHNOLOGIES INC.
LONDON, ONTARIO, CANADA

DESCRIPTION: WD, UV3 UC DAVIS CA
THIRD ANGLE PROJECTION
1.0" ON ORIGINAL DWG
SCALE: NTS
PART NO. 3E1026
REV D
SHEET 1 OF 9
SIZE D
DWG NO. 3E1026